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Estimating Total Factor Productivity and Its Components: Evidence from Major Manufacturing Industries of Pakistan

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1. INTRODUCTION

Manufacturing sector of Pakistan accounts for 19.1 percent of GDP and is the second largest sector of the economy. It grew by 8.4 percent during 2007 as against 10 percent last year. In the manufacturing sector, large scale manufacturing (LSM), plays a vital role and accounts for approximately 70 percent of overall manufacturing [*Economic Survey of Pakistan* (2006-07)]. During 2006-07 relatively slower pace of expansion exhibits signs of moderation on accounts of higher capacity utilisation, difficulties in the textile sector and lower than expected scale of operations of oil refineries. A number of other factors have also contributed to the low pace of expansion in manufacturing including zero percent growth in raw cotton production which is a critical input for the textile industry, vegetable ghee and cooking oil which comprise about 5.5 percent of the LSM sector, showed uninspiring performance due to unparalleled rise in international palm and soybean oil prices. The performance of the automobile sector has been far less impressive this year as compared to previous five years due to a fall in domestic demand for cars on account of increasing auto financing rates. The higher imports of used cars in the beginning of fiscal year 2006-07 also affected the performance of domestic auto mobile sector.

As an important sector in the overall economic growth, manufacturing sector requires an in depth analysis at industry and corporate level. The performance and financial position of the corporate sector is a major determinant of financial stability. Manufacturing sector is dominated by textile sector in terms of assets, size and credit allocation.

This paper has performed a detailed analysis of different industries in the manufacturing sector to sort out the efficient sector in terms of total factor productivity,

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technical efficiency change and technical change using aggregate firm level data and variables. There are few studies on the manufacturing sector of Pakistan which used macro level data, variables and different approaches to measure the total factor productivity like Afzal (2006) and Mahmood, *et al.* (2007).

Different performance measures are used by different firms to evaluate the efficiency and effectiveness of their business processes and strategic objectives [Wang (2006)]. These performance measurement tools are used to evaluate resource allocation process to determine that how these resources can be managed and distributed in a better way to the appropriate level. The relationship between resources and their use in producing output needs to be established for the organisations to determine whether these resources have been properly allocated to get the desired output. When the deficiencies are quantified in the performance of organisation, it will help the organisation's decision-makers and policy makers to monitor the performance over time [Hannula, *et al.* (1999)]

Productivity growth studies at the country level are usually based on the overall or aggregate data; therefore, results of those studies are average of the overall economy which comprises of different sectors. Hence contribution in each country's productivity has different proportion of sectors. The growth in these sectors will have major impact on the productivity growth. Like for America and Australia, agriculture is the major sector which contributes to economic growth. For Singapore, which is a small and open economy, has different industrial structure and services as a major contributing sector. So it is dire need that productivity should be estimated on sector level. There are a number of studies which applied productivity and efficiency analysis. Manufacturing studies include Diaz and Sanchez (2008), Idris and Rahmah (2006), Mahadevan (2002), Fare, *et al.* (2001), Bjurek and Durevall (2000), Rao and Shandre (1998a, 1998b), Baldwin and Rafiquzzaman (1994), Wong (1993), Oulton and O Mahony (1994), Hazledine (1985) and Todd (1984).

Comprehensive know how of productivity changes is important for the policymakers because growth in productivity is an important source of economic growth. There are two different factors which bring productivity change; One is the adoption of technical innovation in the product and processes and the other is capacity of firms to increase production with given input and technology. A productivity comparison between different sectors can also lead to the source of industrial growth and will also help in resource allocation to different sectors [Angeles and Sanchez (2008)].

There are some studies on manufacturing sector of Pakistan which include Mahmood, *et al.* (2007) that has estimated the efficiency of large scale manufacturing in Pakistan using production frontier approach. Afzal (2006) has estimated the total factor productivity for large scale manufacturing using three different approaches while Burki and Khan (2005) analysed the implications of allocative efficiency on resource allocation and energy substitutability for large scale manufacturing. These studies have used aggregate data of the sectors and economy. All these studies used data upto 2001. There are no reported studies of total factor productivity growth at sector level using aggregate of firms' level data in the form of input and output variables in Pakistan.

The basic objective of this paper is to use the data envelopment analysis as a tool for the measurement of total factor productivity growth for important manufacturing industries. The objective is also to decompose TFP growth into technical change, technical efficiency change and scale efficiency change for understanding the source of productivity for Pakistani manufacturing sectors/industries listed at Karachi Stock Exchange. From individual sector's perspective, this study could help decision makers to assess the sectors performance and can take steps to increase their productivity and efficiency.

The next section presents the literature review. Data, variable issues and methodology are discussed in Section 3. Section 4 presents the empirical results, while Section 5 concludes the finding of this study.

2. LITERATURE REVIEW

Productivity growth and technical efficiency has been estimated in number of studies at sectoral level for different types of industries using both parametric and non-parametric methodology. In parametric methodology, Stochastic Frontier analysis is performed while in the non-parametric methodology, Data Envelopment analysis is used.

Diaz and Sanchez (2008) analysed the performance of the small and medium Spanish manufacturing firms during 1995-2001. The focus of the study was on the technical inefficiency and its determinants for these firms using stochastic frontier production function. The findings of the results suggested that small and medium firms are more efficient than large firms and these small firms can easily exit the market under economic difficulties. Further if the market share, foreign shareholders, proportion of temporary over fixed workers, the intensity of capital and firm legal status are controlled, small and medium sized firms tend to be more efficient.

Basti and Akin (2008) compared the productivity of domestic owned and foreign owned firms operating in Turkey. They selected non financial firms listed on Istanbul Stock Exchange for the period 2003-2007. Nonparametric technique called DEA was used to calculate Malmquist Index as measurement of productivity. This Malmquist productivity was further decomposed into efficiency change and technical change. The results of the study indicated that there were no differences in terms of productivity of domestic owned and foreign owned firms. The average productivity of both times of firms decreased throughout the period under analysis except 2006.

The efficiency of the large scale manufacturing sector of Pakistan was examined by Mahmood, *et al.* (2007) using the stochastic production frontier approach. This frontier was estimated for two periods 1995-96 and 2000-01, for 101 industries at the 5-digit PSIC. The results of this study showed that there was some improvement in the efficiency of the large scale manufacturing sector, although the magnitude was small. The results were mixed at the disaggregated level, whereas a majority of industries had gained in terms of technical efficiency and some industries were also weaker in terms of their efficiency level.

Afzal (2006) estimated total factor productivity for the large scale manufacturing sector from 1975 to 2001 using three different approaches. In the first approach classical models were used and comparison of four models was made. Simultaneous equation approach was used at second step to measure the contribution of factors affecting productivity of large scale manufacturing. At third step, autoregressive models were used to forecast productivity. Overall results showed that productivity was affected by many factors like labor, capital, Gross National Product and per capita income. Further, different economic models were applicable and predictable to the data of large scale manufacturing sector of Pakistan and macroeconomic policies might help in improving productivity of large scale manufacturing sector.

Kong and Tongzon (2006) examined the total factor productivity for ten major sectors of Singapore during 1985-2000. They used the non-parametric, frontier methodology known as Data Envelopment Analysis (DEA) to calculate the Malmquist Productivity Index at sectoral level. The analysis of the results identified the best practiced sectors and straggler in terms of efficiency change, technical change and total factor productivity change. These three productivity estimates were also adjusted for the effect of inflation and business cycles so these became more reliable for policy making.

Wang (2006) used the DEA and Balanced Scorecard (BSC) technique to measure the corporate performance efficiency of Acer Incorporation (computer manufacturer) based in Taiwan. Annual report data was used from 2001 to 2003 to evaluate performance using DEA and BSC approach. The findings produced by DEA offered a confirmation of Acer's strategy in 2003. Acer had been able to create value added products without increasing its cost. Further it had engaged in effort to low inventory, therefore allowed to reduce overhead cost and increase efficiency. Balance Scorecard highlighted the importance of research and development expenditures in the performance of all key aspects.

The concept of productivity measurement and change has been applied to the non financial sector. Angelidis and Lyroudi (2006) examined the productivity for Italian banks for period 2001-2002. They used the nominal values and natural logarithm of these values as input and output. Productivity change was calculated using Malmquist Productivity Index. The relationship between size of bank and its performance was measured using correlation and ranking correlation. The results suggested that bank size and performance has inverse relationship but it was not significant.

One of the studies by Fu (2005) for panel of Chinese manufacturing industry was carried out to estimate Total Factor Productivity (TFP). TFP growth was estimated for period 1990-1997 using Malmquist Productivity Index. This Index was decomposed into technical progress and efficiency change. The analysis of the results showed that there was no evidence of significant productivity gains at industry level as a result of exports in a transition economy. It was suggested that a developed domestic market and a neutral outward oriented policy is necessary for exports to generate positive effect on TFP growth.

In Pakistan's economy context, Burki and Khan (2005) analysed the implications of allocative efficiency on resource allocation and energy substitutability. The study covered the period 1969-70 to 1990-91 and utilises pooled time series data from Pakistan's large scale manufacturing sector to estimate a generalised translog cost function. The results pointed out strong evidence of allocative inefficiency leading to over or under-utilisation of resources and higher cost of production.

The effect of food shortage on technical efficiency and profitability was analysed in Spanish live stock sector by Iraizoz, *et al.* (2005). They estimated the parametric stochastic production frontier production functions with inefficiency effects. The results of this analysis suggested ineffectiveness of agricultural policy regulations in promoting efficiency for this sector. While the profitability analysis revealed the importance of direct subsidies. These subsidies were having two counter effects. On one side, they allowed farmers to meet their input cost and on the other side, they had a negative impact on technical efficiency.

Fare, Grosskopf and Margaritis (2001) analysed the relative trend in the total factor productivity in Australia and New Zealand for the manufacturing sector during 1986-1996. Their objective was to see whether reforms in the two countries have impact on the productivity performance because both countries had a major structural change with different pace and intensity. Malmquist Productivity Index was used to calculate the total factor productivity. Further it was decomposed into technical efficiency and technical change which helped in analysis to check the source of TFP in the relative performance for two countries. In general, the results suggested that New Zealand performed better than Australia in terns of total factor productivity for manufacturing sector. This lower TFP in Australia was due to low capital intensity in the production process. Further the major source of TFP growth in New Zealand was technical change rather efficiency change.

The productivity growth in the sixteen manufacturing sectors was analysed by Fare, Grosskopf and Lee (1995) for period 1978-1992. Data Envelopment Analysis was used to calculate the Malmquist Productivity Index. Further decomposition of TFP into efficiency change and technical change was also made for in depth analysis of source of productivity. Technical change was also decomposed into input bias, output bias and magnitude part. The results suggested that the manufacturing sector's productivity increase by 2.89 percent per annum while there were large differences among sub sectors. It was also found that productivity slightly increased due to scale change. While high technical progress was due to industry up gradation policies and increased research and development activities.

Bjurek and Durevall (2000) analysed the increase in total factor productivity for Zimbabwe's manufacturing sub sectors against the structural adjustment program implemented from 1991 to 1995. Malmquist productivity Index was used to evaluate productivity for thirty one manufacturing sub sectors for the period 1980 to 1995. Further econometric methods were used to test the effect of trade reforms and market liberalisation to the structural adjustment program. In general the results suggested a great variation in growth rates across sectors and over time period. There was no growth in the total factor productivity during structural adjustment program except for the last two years where most of the sub sectors showed a growth in total factor productivity. The results of econometric analysis showed only import growth as influencing variable and all other variables measuring trade liberalisation had no influence on productivity growth.

Fare, Grosskopf, and Lee (1995) made an analysis of productivity in four Taiwanese manufacturing industries during 1978-1989 by decomposing the Malmquist productivity change index into technical change and technical efficiency change. Further this method was also compared to traditional and parametric approaches. The results of this study suggested that TFP growth in the long run was totally because of the technical change. On average the liberalisation period's TFP is higher than the pre liberalisation period. Further results suggested that technical efficiency and technical progress may not move together and technical change was positively related with R&D.

3. METHODOLOGY

3.1. Malmquist TFP Index

Data Envelopment Analysis (DEA) in a linear-programming methodology where we use input and output data for Decision Making Units (DMU). In our study, each sector is a Decision Making Unit (DMU). The DEA methodology was initiated by Charnes, *et al.* (1978) who built on the frontier concept started by Farell (1957). The methodology used in this paper is based on the work of Fare, *et al.* (1994) and Coelli, *et al.* (1998). We have used the DEA-Malmquist Index to calculate the total factor productivity growth in different sectors listed at Karachi stock exchange. The Malmquist TFP Index measures changes in total output relative to input. This idea was developed by a Swedish statistician Malmquist (1953). It is a suitable methodology because of following reasons [Mahadevan (2002)].

First, the data envelopment analysis approach is an improvement over translog index approach. In translog approach, technical inefficiency is ignored and it calculates only technical change which is wrongly interpreted as TFP growth. While in the literature of productivity, TFPG is composed of technical change and technical efficiency. Second, DEA also identify the sources of TFP growth which will help the policy makers to indentify the specific source of low TFP growth. Another advantage of nonparametric nature of DEA is that it reveal best practice frontier rather a central tendency properties of frontier. In DEA there is also no need to estimate any production function. This Malmquist productivity index can be decomposed into efficiency change, Technical change and total factor productivity growth. TFPG is geometric mean of efficiency change and technical change. We have used the DEAP software developed by Coelli (1996) to compute these indices. A simple framework of Malmquist productivity index can be found in Mahedevan (2004). Fare, *et al.* (1994) suggests that if suitable panel data are available, the required distance measures of Malmquist Total Factor Productivity Index can be calculated using DEA. They have defined the output based MTFPI as a geometric mean of two indices.

Following Fare, *et al.* (1994), the output oriented Malmquist TFP index between two periods *s* and period *t* is given by

$$m_0(y_s, x_s, y_t x_t) = \left[\frac{\mathrm{d}_0^{\mathrm{s}}(y_t, x_t)}{\mathrm{d}_0^{\mathrm{s}}(y_s, x_s)} \mathrm{X} \frac{\mathrm{d}_0^{\mathrm{t}}(y_t, x_t)}{\mathrm{d}_0^{\mathrm{t}}(y_s, x_s)} \right]^{\frac{1}{2}} \quad \ldots \quad \ldots \quad (1)$$

In the above equation, $d_0^s(y_t, x_t)$ represents the distance from the period *t* observation to the period *s* technology, *y* represents output and *x* represents input. A value of m_o greater than one indicates positive growth in TFP from period *s* to period *t* and value less than one shows a decline in TFP. This productivity index can also be written in the following way.

$$m_0(y_s, x_s, y_t x_t) = \frac{\mathrm{d}_0^{\mathrm{t}}(y_t, x_t)}{\mathrm{d}_0^{\mathrm{s}}(y_s, x_s)} \left[\frac{\mathrm{d}_0^{\mathrm{s}}(y_t, x_t)}{\mathrm{d}_0^{\mathrm{t}}(y_t, x_t)} \mathrm{X} \frac{\mathrm{d}_0^{\mathrm{s}}(y_s, x_s)}{\mathrm{d}_0^{\mathrm{t}}(y_s, x_s)} \right]^{\frac{1}{2}} \quad \ldots \quad (2)$$

Where the ratio outside the bracket measures technical efficiency change between period s and t. The other part of Equation 2 measures the technical change which is geometric mean of the shift in technology between two periods evaluated at x_t and x_s.

We can decompose the total factor productivity growth in following way as well.

MTFPI = Technical Efficiency Change X Technical change
(Catching up effect) (Frontier Effect)

MTFPI is the product of measure of efficiency change (catching up effect) at current period *t* and previous period *s* (average geometrically) and a technical change (frontier effect) as measured by shift in a frontier over the same period. The catching up effect measures that a firm is how much close to the frontier by capturing extent of diffusion of technology or knowledge of technology use. On the other side, frontier effect measures the movement of frontier between two periods with regard to rate of technology adoption. In DEA-Malmquist TFP Index does not assume all the firms or sectors are efficient therefore, any firm or sector can be performing less than the efficient frontier.

In this methodology, we will use the output oriented analysis because most of the firms and sectors have their objectives to maximise output in the form of revenue or profit. It is also assumed that there is a constant return to scale (CRS) technology to estimate distance functions for calculating Malmquist TFP index. Otherwise, the results may not reflect the TFP gains or losses resulting from scale effects.

3.2. Input and Output Variables

Data Envelopment Analysis approach can be applied to those firms, who produce revenue. This can be done by converting the financial performance measures to the firm's technical efficiency equivalents. While using input and output variables, we have followed the methodology of Feroz, *et al.* (2003) and Wang (2006). One of the methods is to disaggregate Return on Equity (ROE) using the DuPont model. Therefore, return on equity which measures the relation between net income and common equity can be divided into profit margin, total assets turnover and equity multiplier. This process of measuring financial performance indicators can be converted into output and input variables.

The general return on equity formula using DuPont ratio can be written as

$$Return\ Equity = \frac{Net\ Income}{Sales}\ X\ \frac{Sales}{Total\ Assets}\ X\ \frac{Total\ Assets}{SH\ Equity} \quad \dots \quad \dots \quad (3)$$

In the above equation profit margin is net income/Sales; assets turnover or utilisation is sales / total assets; equity multiplier is total assets/equity. This breakdown helps us to examine return on equity in terms of a measure of profitability (profit margin), assets turnover or assets required to generate sales and for financing of assets (equity multiplier). These above components; sales, net profit, total assets and equity are important aspects of technical efficiency for the revenue producing firms. Accordingly sales, total assets and shareholder's equity can be used as input and net profit as output which needs to be maximised. Data envelopment analysis program does not support negative values while net profit can be negative in terms of loss, hence using profit as output is not appropriate. This problem can be solved by redefining the input variables as total assets, Shareholder's equity, cost of goods sold and operating expenses while sales revenue of the firm as output.

The above methodology helps us to logically convert performance ratios into efficiency. In this way long term resources total assets and equity and short term resources cost of goods sold and operating expenses are used to produce output in the form of sales revenue.

3.3. Data

This study covers eleven major manufacturing sectors listed at Karachi Stock Exchange including automobile assembler, automobile parts and accessories, chemical, cement, pharmaceutical, oil and gas exploration and refinery, oil and gas marketing, engineering, textile composite, textile spinning and textile weaving. There are 228 firms listed in these sectors on Karachi stock exchange. The data is collected for those firms which not only remained listed on the KSE during 1998 to 2007, but also performed operations during this time period. Considering the imitates of Data Envelopment Analysis Program (DEAP) only those firms are included in analysis which have their equity in positive their annual reports were available for all the ten years from 1998 to 2007. Therefore, finally 125 firms are included in the sectoral analysis. We have calculated the Total Factor Productivity Growth and its components using Malmquist productivity Index for these eleven sectors.

4. RESULTS AND DISCUSSION

Industries growth in terms of output during period 1998 to 2007 is presented in Table 1. The average nominal growth is also adjusted for effect of inflation resulting in average real growth rate.

Table 1

Growth of Manufacturing Industries during 1998-2007

Sector	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	Avg. Nominal	Avg. Real
Automobile Assembler	24.98	–2.61	20.91	13.26	42.05	40.26	35.76	30.60	–0.14	**22.79**	17.22
Automobile Parts	21.35	5.69	5.85	–3.32	20.61	31.75	19.35	21.08	12.98	**15.04**	9.47
Cement	33.44	20.80	-8.94	2.81	–1.00	38.91	31.09	45.34	-6.45	**17.33**	11.76
Chemical	30.52	-18.73	21.60	11.69	23.34	15.60	12.72	10.07	7.88	**12.74**	7.17
Engineering	–11.53	10.01	21.15	15.86	20.11	19.23	69.29	-0.39	33.93	**19.74**	14.17
Oil and gas Expl. and Refinery	–7.64	74.28	21.68	-13.74	26.79	7.76	4.51	98.96	4.98	**24.18**	18.61
Oil and Gas marketing	–15.08	72.72	31.58	0.52	21.97	6.78	27.83	31.51	9.98	**20.87**	15.30
Pharmaceutical	–5.47	11.40	52.40	9.41	15.38	11.26	9.40	10.95	4.77	**13.28**	7.71
Textile Composite	10.62	7.82	16.26	7.15	10.14	18.59	–15.11	39.41	15.97	**12.31**	6.74
Textile Spinning	5.76	13.10	12.48	–4.87	10.53	23.90	–22.70	47.40	14.32	**11.10**	5.53
Textile Weaving	2.73	3.23	4.77	–3.01	5.81	35.36	–23.05	49.82	2.02	**8.63**	3.06
Average Nominal	**8.15**	**17.98**	**18.16**	**3.25**	**17.79**	**22.67**	**13.55**	**34.98**	**9.11**	**16.18**	10.61
Average Real	2.45	14.38	13.76	-0.25	14.49	18.07	4.25	27.08	1.31	10.62	

Overall manufacturing sector grew by 10.61 percent during 1998-2007. Oil and gas and automobile sectors are on the top in terms of average real growth. During year 2001-02, average real growth is in negative and is very low during years 1998-99 and 2006-07. Average real growth rate is highest during 2005-06. The textile sectors are the lowest growing sectors in terms of nominal and real growth rate.

The TFP Index technique is used to construct a grand frontier based on the data from all sectors. Each sector is compared to the frontier. Technical efficiency is how much closer a sector gets to the grand frontier and how much this grand frontier shift at each sector observed input mix is called technical change.

We have calculated Malmquist total factor productivity and efficiency change, technical change, pure technical efficiency and scale change component for all the industries in the sample. A summary description of the average performance of industries over the entire period is presented in Table 2.

Table 2

Malmquist Index of Sector Means (1998-2007)

No.	Industry	TFP Change	TE Change	Tech. Change	PE Change	SE Change
1	Automobile Assembler	1.013	1.000	1.013	1.000	1.000
2	Automobile Parts and Accessories	1.002	1.011	0.992	1.000	1.011
3	Cement	1.023	1.030	0.993	1.027	1.002
4	Chemical	1.016	1.026	0.991	1.026	1.001
5	Engineering	1.007	1.014	0.994	1.006	1.008
6	Oil & Gas Exploration and Refinery	1.020	1.000	1.020	1.000	1.000
7	Oil and Gas Marketing	1.038	1.016	1.024	1.000	1.016
8	Pharmaceutical	1.005	1.000	1.005	1.000	1.000
9	Textile Composite	0.993	1.012	0.984	1.013	0.999
10	Textile Spinning	0.998	1.017	0.984	1.015	1.002
11	Textile Weaving	0.988	1.007	0.982	1.000	1.007
Mean All Industries		**1.009**	**1.012**	**0.998**	**1.008**	**1.004**

4.1. Total Factor Productivity Growth in Industrial Sector

In Table 2, the bottom line shows that manufacturing industries experienced an overall positive TFP growth of 0.9 percent during 1998-2007. The analysis of industries revealed that eight out of eleven industries enjoyed positive TFP growth. The overall TFP growth is positive due to improvement in technical efficiency of 1.2 percent and all industries have their technical efficiency ranges from 1.000 to 1.027. This result reveals that improvement in these industries is due to their productivity based catching up capability. On the other side where the technical change is less than unity, has a negative effect on the overall TFP growth. The overall technical change in 7 out of 11 industries is less than 1 which is a main cause in dampening the total factor productivity for industries. Technical efficiency change is the result of pure technical efficiency change and scale efficiency change. With regards to pure efficiency change, it is one or more than one in most of the industries. In case of Scale efficiency change, value close to unity shows that most of the industries are operating at optimum scale. Therefore, both Scale efficiency and pure technical efficiency have contributed to the improvement in Technical efficiency.

As can be seen from the Table, the comparison of total factor productivity change in different industries shows that oil and gas marketing sector on average has the highest growth in TFP (3.8 percent) during 1998 to 2007, followed by the cement sector that has (2.3 percent) total factor productivity growth. The worst performer in terms of total factor productivity growth is the textile sector which includes spinning, composite and weaving. Total factor productivity of the textile sector decreased on average by –0.80 percent, –0.20 percent and –1.2 percent in the composite, spinning and weaving sectors respectively.

4.2. Total Factor Productivity Growth

The comparative results of individual industries in terms of productivity for each year during 1998-2007 are presented in Table 3, which explains the total factor productivity change for all sectors on yearly basis and provides a comprehensive understanding about the performance of different sectors.

Table 3

Comparative Total Factor Productivity of All Sectors during (1998-2007)

Sector	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	Mean
Automobile Assembler	1.021	1.004	1.086	0.940	1.042	0.989	0.985	1.058	0.990	**1.013**
Automobile Parts	1.016	1.028	0.983	0.989	1.038	1.020	0.969	0.995	0.981	**1.002**
Cement	1.036	1.168	0.880	1.120	0.917	1.240	1.000	1.096	0.750	**1.023**
Chemical	1.007	1.116	0.989	0.983	1.017	1.049	0.985	1.009	0.990	**1.016**
Engineering	1.031	0.963	1.014	1.111	0.943	0.993	1.013	0.998	0.999	**1.007**
Oil and Gas Expl.and Refinery	0.887	1.229	1.022	0.782	1.099	0.934	0.957	1.297	0.975	**1.020**
Oil and Gas marketing	0.999	1.080	1.067	0.956	1.101	0.941	1.081	1.081	1.037	**1.038**
Pharmaceutical	1.040	1.033	0.995	1.003	1.037	1.007	0.980	0.977	0.977	**1.005**
Textile Composite	0.988	1.066	0.958	0.993	0.969	0.979	0.996	0.995	0.989	**0.993**
Textile Spinning	0.995	1.067	0.956	0.973	0.989	0.989	1.004	1.019	0.991	**0.998**
Textile Weaving	0.971	0.991	0.962	1.002	0.997	1.009	0.980	1.007	0.972	**0.988**
Mean	**0.998**	**1.065**	**0.991**	**0.983**	**1.012**	**1.011**	**0.995**	**1.045**	**0.965**	**1.009**

In the first year of analysis, pharmaceutical sector is the best performer among all the sectors with TFP growth 4 percent followed by cement sector where the productivity increased by 3.6 percent. Oil and gas exploration and refinery is the worst performer (–11.3 percent) with textile (composite, weaving) sector. During year 1999-00, the total factor productivity of all the sectors, except textile weaving and engineering, increased with oil and gas exploration and refinery, cement and chemical top in ranking with productivity change of 22.9 percent, 16.8 percent and 11.6 percent respectively. This year was also the most favorable for overall manufacturing sector where the total factor productivity increased by 6.5 percent, i.e., highest for the overall manufacturing sector during 1998-2007. In the next year 2000-01, again the TFP changed for all sectors except automobile assembler sector; both oil sectors and engineering are in negative. In this year, automobile assembler sector has highest TFP growth 8.6 percent and also has the highest growth in a year during 1998 to 2007. In the year 2001-02, again a tangle up trend similar to year 2000-01 can be seen where only four sectors (cement, engineering, pharmaceutical and weaving) has their TFP more than 1 and cement is top in ranking with 12 percent growth. Oil and Gas sectors with Automobile, chemical and pharmaceutical sectors perform during 2002-03 where the TFP for the both oil and gas marketing and oil and gas exploration topped in ranking with growth of 10.1 percent and 9.9 percent respectively. Cement sector played a leading role in total factor productivity growth of industrial sector with highest (best performance) 24 percent during 2003-04. Year 2004-05 was suitable only for the oil and gas marketing sector and engineering sector in terms of total factor productivity, while all other sectors have their productivity growth in negative. In this year oil and gas marketing sector's productivity increased by 8.1 percent and engineering sector's by 1.3 percent while the cement sector has no increase or decrease in productivity growth. Overall manufacturing sector also performed better during year 2005-06 where 7 out of 11 sectors have their TFP growth above than 1 and manufacturing sector grew by 4.5 percent. Oil and gas exploration and refinery has the highest total factor productivity change 29.7 percent and cement next in ranking with 9.6 percent change. Oil and gas marketing sector has 8.1 percent TFP change in this year. Year 2006-07 was a crucial year for the overall manufacturing sector where the productivity change for all the sectors declined except for oil and gas marketing sector where it increased by 3.7 percent.

In terms of total factor productivity change, oil and gas sector and cement sector has relatively more stable results. In both sectors TFP change in six out of nine years is greater than unity. Due to this reason, these sectors topped in ranking in terms of total factor productivity. As discussed earlier year 2006-07 was the most crucial year for all the sectors where TFP declined for all sectors. If we exclude this year from our analysis, the overall TFP growth for the manufacturing sector would increase to 1.25 percent which is now 0.7 percent including year 2007. The exclusion of this year from analysis will also replace the ranking for both sectors and cement sector will be the most stable one and best performer in all sectors while the oil and gas marketing sector will be the next in the ranking. Textile sector (Composite, spinning and weaving) is the worst performer throughout study period in terms of TFP except in few years where it is positive. If we see textile composite sector, it has negative productivity change in all years except in the year 2000. Similar type of result is for the spinning sector where the TFP is negative in seven out of nine years. Textile weaving sector has highest overall negative growth (–1.2 percent) among all the sectors. This analysis will induce us to highlight that stability in terms of bad performance (negative TFP change) is reflected in the textile sector throughout the years from 1998-2007.

The indices of total factor productivity have been decomposed into technical efficiency change also called managerial efficiency and technical (technological adoption) change. These two sources of productivity are presented in the next section.

4.3. Managerial Efficiency Growth

Technical efficiency change can make use of existing input to produce more of same product. As one gets more experience in producing some product, it becomes more and more efficient in it. Labour finds new ways to produce by making minor modifications in the process of manufacturing which contribute to higher productivity. Therefore, to understand the contribution made by technical efficiency in the productivity growth, a sector-wise technical efficiency movement is presented in Table 4.

Table 4

Comparative Technical Efficiency Change in all industries during (1998-2007)

Sector	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	Mean
Automobile Assembler	1.000	0.997	1.003	1.000	1.000	1.000	1.000	1.000	1.000	**1.000**
Automobile Parts	1.106	0.988	1.013	0.992	1.001	1.007	0.964	1.025	1.003	**1.011**
Cement	1.196	1.066	0.949	1.054	0.955	1.047	1.000	1.000	1.000	**1.030**
Chemical	1.119	1.047	1.025	0.950	1.028	1.042	0.977	1.040	1.009	**1.026**
Engineering	1.102	0.912	1.063	1.049	0.973	0.968	1.003	1.025	1.031	**1.014**
Oil and Gas Exp. and Refinery	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	**1.000**
Oil and Gas Marketing	1.143	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	**1.016**
Pharmaceutical	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	**1.000**
Textile Composite	1.127	0.995	1.006	0.965	0.979	0.959	0.990	1.001	1.085	**1.012**
Textile Spinning	1.176	1.007	1.000	0.969	0.958	0.998	0.986	1.045	1.016	**1.017**
Textile Weaving	1.119	0.981	0.989	0.985	0.986	1.024	0.975	1.017	0.991	**1.007**
Mean	**1.097**	**0.999**	**1.004**	**0.996**	**0.989**	**1.004**	**0.991**	**1.014**	**1.012**	**1.012**

In general, these results suggest that technical efficiency is an important contributor in the total factor productivity. The average efficiency change for each sector is equal or greater than one. During 1998-99, being the first year of analysis, the technical efficiency change for all sectors is positive and overall manufacturing sector efficiency increased by 9.7 percent, being the highest efficiency growth in entire period. Cement, textile spinning and oil and gas marketing sectors are at the top with 19.6 percent, 17.6 percent and 14.3 percent efficiency change respectively. Cement sector continued its top position in terms of efficiency change in the following year 1999-2000 where it increases by 6.6 percent. Chemical sector also continued to improve efficiency with 4.7 percent. The results in the above table also explain that four sectors including both oil and gas, pharmaceutical and automobile assembler sectors did not show any change in terms of efficiency during 1998-2007. The cement sector performed relatively better than all other sectors in terms of efficiency change as it topped in raking during years 1998-99, 1999-00, 2001-02, 2003-04. Other good performing sectors in terms of efficiency change are chemical, engineering and automobile parts. These sectors have their efficiency change in positive for seven and six years out of nine years.

4.4. Technology Adoption

The second important source of total factor productivity growth is the change in the technology. As Squires and Reid (2004) articulated that technological change is the development of new technologies or new products to improve and shift production frontier upward Table 5 presents the comparative technical change for all sectors during period 1998 to 2007. In general, the technical change can be seen in two oil sectors, automobile and pharmaceutical sector where it is 2.4 percent, 2.0 percent, 1.13 percent and 0.5 percent respectively. In year 1998-99, the comparative technical change shows declining trend for all sectors except Pharmaceutical and automobile sectors where it increased by 4 percent and 2.1 percent. During this year efficiency of manufacturing sector decline by 9 percent and it is the highest decline rate during period 1998-2007. Year 1999-00 was a better year in terms of technical change where it was positive for all the manufacturing sub sectors and manufacturing sector overall recorded a highest 6.7 percent technical progress. In this year both oil and gas and cement sectors were on the top in raking in terms of technological change. In year 2000-01, automobile assembler and both oil and gas sectors have a positive technical change while all other sectors experienced negative technical change. Cement sector was also on top in ranking during the years 2001-02 and 2003-04 where the technical change increased by 6.2 percent and 18.4 percent. This sector also performed better during 2005-06 but worst in year 2006-07 where its technical change drop by 25 percent. If year 2006-07 would be excluded from analysis, this sector has a relatively stable and overall positive technical change. Year 2006-07 was a dreadful year for manufacturing sector where the technical change dropped for all the sub sectors except for oil and gas marketing sector which increased by 3.7 percent. Oil and gas marketing sector is the most stable sector in terms of technological change as having its change more than unity for six out of nine years. This sector also topped in ranking based upon the technical progress during the years 2002-03, 2004-05 and 2006-07. Automobile assembler and pharmaceutical sectors are also better in terms of technical progress over 1998-2007.

Table 5

Comparative Technical Change in All Industries during (1998-2007)

Sector	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	Mean
Automobile Assembler	1.021	1.008	1.083	0.940	1.042	0.989	0.985	1.058	0.990	**1.013**
Automobile Parts	0.919	1.041	0.971	0.997	1.037	1.012	1.005	0.970	0.978	**0.992**
Cement	0.866	1.096	0.927	1.062	0.960	1.184	1.000	1.096	0.750	**0.993**
Chemical	0.900	1.066	0.965	1.035	0.989	1.006	1.008	0.969	0.981	**0.991**
Engineering	0.935	1.056	0.954	1.059	0.968	1.025	1.010	0.973	0.969	**0.994**
Oil and Gas Exp. and Refinery	0.887	1.229	1.022	0.782	1.099	0.934	0.957	1.297	0.975	**1.020**
Oil and Gas Marketing	0.875	1.080	1.067	0.956	1.101	0.941	1.081	1.081	1.037	**1.024**
Pharmaceutical	1.040	1.033	0.995	1.003	1.037	1.007	0.980	0.977	0.977	**1.005**
Textile Composite	0.876	1.072	0.953	1.029	0.990	1.020	1.006	0.994	0.912	**0.984**
Textile Spinning	0.846	1.060	0.956	1.004	1.032	0.991	1.018	0.975	0.975	**0.984**
Textile Weaving	0.867	1.010	0.972	1.017	1.012	0.986	1.004	0.990	0.981	**0.982**
Mean	**0.910**	**1.067**	**0.987**	**0.986**	**1.023**	**1.007**	**1.005**	**1.031**	**0.954**	**0.998**

Table 6 presents the ranking of all the sectors in terms of total factor productivity growth, technical efficiency change and technical change. This table also presents the ranking in terms of pure efficiency change and scale efficiency change being the components of technical efficiency change.

Table 6

Ranking of Sectors based on Malmquist TFP and its Components

Ranking	Industry	TFP Change	Industry	TE Change	Industry	Tech. Change
1	Oil and Gas Marketing	1.038	Cement	1.030	Oil and Gas Marketing	1.024
2	Cement	1.023	Chemical	1.026	Oil & Gas Expl. and Refinery	1.020
3	Oil & Gas Expl. and Refinery	1.020	Textile Spinning	1.017	Automobile Assembler	1.013
4	Chemical	1.016	Oil and Gas Marketing	1.016	Pharmaceutical	1.005
5	Automobile Assembler	1.013	Engineering	1.014	Engineering	0.994
6	Engineering	1.007	Textile Composite	1.012	Cement	0.993
7	Pharmaceutical	1.005	Automobile Parts and Accessories	1.011	Automobile Parts and Accessories	0.992
8	Automobile Parts and Accessories	1.002	Textile Weaving	1.007	Chemical	0.991
9	Textile Spinning	0.998	Automobile Assembler	1.000	Textile Composite	0.984
10	Textile Composite	0.993	Oil and Gas Expl. and Refinery	1.000	Textile Spinning	0.984
11	Textile Weaving	0.988	Pharmaceutical	1.000	Textile Weaving	0.982

5. CONCLUSIONS

This paper applied a DEA approach to estimate the total factor productivity growth, technical efficiency change and technological progress in Pakistan's manufacturing sub sectors using panel data for eleven selected industries from 1998 to 2007. Malmquist productivity index was used to measure the productivity growth. Following Fare, *et al.* (1994), this paper decomposed the Malmquist productivity index into technical efficiency and technical change component. This decomposition helped us to identify improvement in efficiency and contribution of technological progress and innovation to productivity growth in manufacturing industries.

The empirical estimates on the manufacturing sub sectors productivity performance yielded several striking results. Overall manufacturing sector improved technical efficiency by 1.2 percent while technical (technological) change put a negative effect on the productivity; as a result the overall total factor productivity during 1998-2007 only increased by 0.9 percent. If we see the TFP and its components in individual year for overall manufacturing sector, it presents divergent trend.

The results from individual industries show that TFP growth is mainly contributed by technical efficiency while the technical change is only positive for four out of eleven industries. It suggests that manufacturing sub sectors are lacking in terms of technological adoption. It is thought that technical progress is closely related to research and development(R & D) activities and industry upgrading policies. Therefore firms in the manufacturing sub sectors need greater investment in (R & D) activities and adoption of new technologies. Increase in skilled worker through human resource development reduces skills shortage which hampers technological adoption.

Further, year wise analysis highlights that there is divergence in all the sectors over 1998-2007 in terms of total factor productivity, technical efficiency and change. Except few industries which have relatively stable include Cement and oil and gas marketing sectors, all industries have a mix trend over 1998-2007 which affects the productivity and ranking of industries.

Oil and gas marketing sector is at the top in ranking in terms of TFP due to highest technical change and technical efficiency. This sector has relatively performed better over the period 1998 to 2007. Cement sector comes next in ranking where the major source is technical efficiency and technical change which remain positive for the entire period except for the year 2006-07 where it decline by 25 percent. Oil and gas exploration, chemical and automobile assembler are also relatively better performer where the technical change is the main source for oil and gas exploration and refinery and automobile sector while the efficiency change is for the chemical sector. The textile sector is among the worst performers in terms of productivity over 1998 to 2007 including composite, spinning and weaving. The main reason for this worst performance is non adoption of new technology.

The research suggests that the Pakistani manufacturing sector must increase total factor productivity in most of the industries under study and efforts must be made to provide a stable pattern to the productivity growth. In manufacturing sector, there is a need to improve both technical efficiency and technological progress. Improvement in technical efficiency requires improvement in quality of input like capital and labor. The management aspect is also very important in terms of capital. These strategies will improve the technical change as well which also relies on managing technology and adoption capability of firms. The research and development (R&D) activities can play a vital role to bring technological progress. Therefore, efforts could be made to increase the research and development (R & D) activities in the manufacturing industries. So that the manufacturing industries can play their significant role in Pakistan's growing industrialisation process.

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